Biological Reduction of Metals

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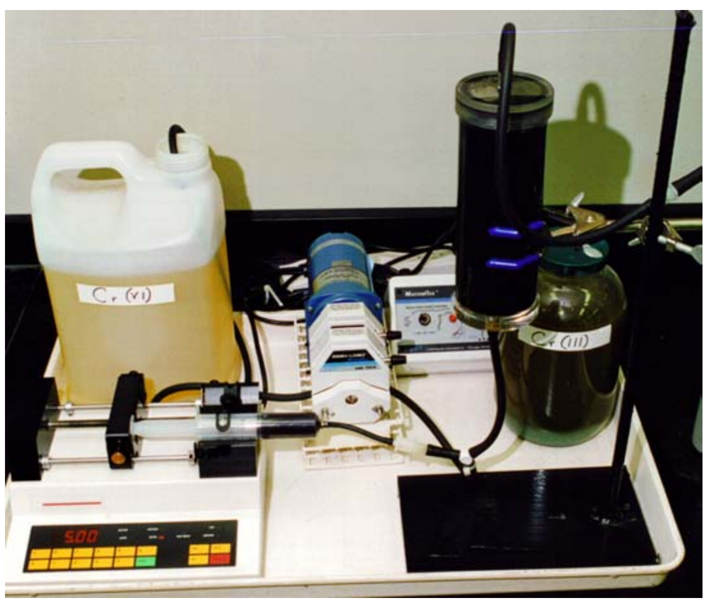
Many sites contaminated with chlorinated solvents are also polluted with metals. Physical methods such as vapor extraction and chemical methods for remediating solvents in soils or deep earth sediments have been successfully used for some time. In situ methods for the remediation of metals, however, including radionuclides (since most are metals), are still being developed. Reducing metals to a nontoxic or stable form (refractory state) in environmental media is in early development. In an environmental toxicity sense, several metals, including uranium, cadmium, and chromium, are of common concern in the U.S. Department of Energy complex. Considerable progress has been made with chromium in its various chemical states in soils and sediments. The following portrayal of chromium illustrates what lies ahead for other environmentally polluting metals, including radionuclides.

Focus

Hexavalent chromium [Cr(VI)] often enters the environment through anthropogenic activity in the forms of chromate ($CrO_4^{=}$) and dichromate ($Cr_2O_7^{=}$). They are regarded as highly toxic and carcinogenic pollutants.



In this lab-scale process, Cr(VI) (characteristic yellow, on left, was pumped into the cylindrical bioreactor where Cr(VI- reducing bacteria were immobilized into porous beads. The resulting Cr(III) exited the bioreactor into the container on the right. Note the characteristic greenish color of Cr(III) precipitate on the bottom. The bacterial feedstock, molasses, was delivered by a syringe pump.

They are very water soluble and mobile pollutants and are also difficult to remove from solution. The main objective of our INEEL research has been to develop a method in which naturally occurring bacteria convert Cr(VI) to the less toxic, less soluble, and less mobile trivalent chromium [Cr(III)]. After bacterial conversion to Cr(III), the chromium can then either be removed from solution through filtration or sedimentation. In most soils, conversion of Cr(VI) to Cr(III) in groundwater will result in adsorption of Cr(III) to the soil and organics. With this technique, we can treat Cr(VI) in groundwater, soil wash effluent, industrial waste streams, and unsaturated soils.

Cr(VI) reducing bacteria are common in most soils. Our approach involves using the microbial ecology and physiology of Cr(VI)-reducing

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aerobes and/or anaerobes that can reduce Cr(VI). These Cr(VI)-reducing bacteria, as part of their normal physiology, reduce Cr(VI) to Cr(III) in both aerobic and anaerobic environments. We have developed selection methods that allow expression of a bacterial population in a bioreactor or in a subsurface dominated by Cr(VI)-reducing bacteria. Cr(VI) is converted (reduced) to Cr(III) very efficiently. Our work shows that the conditions in a bioreactor select not just Cr(VI)-reducing bacteria, but the most efficient Cr(VI) reducers.

This bioprocess can be used for treating soil wash effluent and industrial waste streams. It can also be used in conjunction with pump and treat technologies for groundwater remediation. The technology may be used alone and replace existing, less efficient technologies, or in conjunction with conventional methods as a pretreatment step for surges of Cr(VI), or as a posttreatment polishing step.

We are exploring the possibility of treating Cr(VI)-contaminated soils in place. By exploiting the indigenous Cr(VI) reducers by adding supplemental bacterial nutrients to soils or groundwater, these bacteria could biologically reduce the Cr(VI) to Cr(III) without the need to excavate any soil or sediment, which for deep subsurface cases is not an option. Since Cr(III) is much less soluble than Cr(VI), it could adsorb to the soil or sediment and become immobilized, dramatically minimizing the problem of Cr(VI) contamination. Results to date demonstrate that Cr(VI) reducers in soils could easily be exploited to safely and economically bioreduce Cr(VI) in place.

Selected Publications/Presentations/Patents

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M. A. Rege, J. N. Petersen, D. L. Johnstone, C. E. Turick, D. R. Yonge and W. A. Apel, “Bacterial Reduction of Hexavalent Chromium by *Enterobacter cloacae* Strain Ho1 Grown on Sucrose,” *Biotechnological Letters* (in press), 1997.

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